



# **Snowmass 2021**

## **Instrumentation Frontier**

### **IF07: Electronics and ASICs**

**June 19/2020**

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## - Organization

## - Snowmass Frontiers

## IF7: Electronics/ASICs

co-Conveners:

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## Description

Most R&D will need to be compatible with an extreme environment - e.g. high radiation, cryogenic, space. Current and future custom integration allows higher density, enhanced circuit performance, lower power consumption, lower mass, much greater radiation tolerance or cryogenic temperature performance than is possible with commercial ICs or discrete components. Designs that in the past required significant area on a printed circuit board with many types of specialized chips can potentially be replaced by a single integrated circuit and in some cases, notably pixel detectors, both sensor and readout can be fabricated as part of the same ASIC saving significantly on cost, power per channel and material burden, while improving spatial resolution and potentially replacing highly inefficient data transfer off detector with abstracted parameters.

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# Activities

- **June 6 - Kickoff meeting**
  - More than 30 email subscribers, 60 invitees, 30 participants
  - We encourage those interest to sign up (and to encourage your colleagues to do so)
- **Planning next large meeting (mid July)**
  - **“flash talks” (few minutes) to present areas of interest**
  - Goal: organize among the group a list of topics for further discussions and work in the coming months
- **Topical meetings**
  - A series of meetings, every 2-3 weeks, with each meeting focused on a particular topic
- **Joint meetings**
  - Future electronics needs are driven by physics goals, and the corresponding detector requirements to achieve them
  - Some of the meetings can and will be held together with other IF subgroups (and there will also be discussions between IF and other frontiers)



## IF-07: Electronics and ASICs

- We should cover readout systems, including (but not limited to) their ASICs
- As starting point for background reading, there are some recent studies and reports, including:
  - CPAD Workshops
    - Annual workshops since 2015
    - Most recent (Dec. 2019): <https://wp.physics.wisc.edu/cpad2019/>
    - Report from CPAD 2018 available at <https://arxiv.org/abs/1908.00194>
  - DOE BRN Study Workshop on HEP Detector R&D, Dec. 2019
    - Report expected to be available soon
- Of course, while these are good starting points, new ideas and interests are very welcome as part of Snowmass 2021, which is a community-driven process

# HEPIC High Energy Physics Integrated Circuits

## workshop 2013 ... 2017 ... 2021

- 2013 provided a white paper for previous Snowmass <https://arxiv.org/abs/1307.3241>
- Participants from National Labs and Universities joined together to discuss the technology, workforce development, collaboration and potential funding opportunities to maintain a vibrant challenged, workforce between major detector developments.
- HEPIC feeds into the CPAD process bringing together US scientists and engineers involved in developing integrated circuits for particle physics & related applications.
- Participants are invited to discuss present and future IC & packaging developments to improve the physics reach detector systems.
- Future HEPIC meetings might concentrate on training and creating opportunities for multi institution NDA's allowing future highly complex IC and system designs to be developed and reviewed by a broad swath of our community.
- Our Snowmass activity should encourage this kind of a forum to help foster the continued development of IC technology in High Energy Physics. *Stay tuned for the Volunteer call...*



## IF-07: Electronics and ASICs

- Today's ASIC enabled Front End Readout designs provide the interface between detector specific sensors and the back-end DAQ. The output currency for all systems is **DATA**.
- We expect to learn, perhaps by invitation, about signal processing and readout needs of the other Instrumentation Frontier groups.
- ASICs are becoming quite complex, providing more and more of the complete front end readout with the extremes being to push all data off the detector at high rates, or analyze locally and pushing selected, abstracted data off the detectors... and there is a lot of middle ground.
- The best solutions will be achieved by collaborative design between Detector and Electronics Specialists with a good understanding of the overall system design by all.



## IF-07: Electronics and ASICs


- There are and will be many specialized solutions unique to particular detector system front ends.
- As these unique designs move from the sensor to the back end and to the organization of channels the building blocks become similar making it efficient & expedient to have a seasoned design team with IP blocks that can be scaled and intermingled to optimize the final readout.
- At the same time IC technology has become so complex that a team of experts is required to complete all but the simplest designs.
- As we look to the future, System on a Chip (SoC) designs will become more and more complex. Multiple institutions with relevant understanding of ASIC design will be needed for design, simulation and functional integration into the final ASIC.



## Techniques to Enable Continued Innovations in Instrumentation

- Identify Areas/Topics of Interest for Priority Support by funding agencies: Innovative & Mundane
  - *Some Examples in the following slides*
- Explore inter-agency support for development of ASIC blocks of common interest eg. NNSA & HEP
  - Need for commonly used blocks that must operate in extreme environments, that is not commercially interesting.
- Ensure State of the Art understanding/sharing of designs is broadly accessible within HEP/NP Instrumentation Groups to allow multi-institutional development as needed for complex SoC designs.
  - Encourage Continued use of common CAD tool platforms: eg. Cadence
  - Advocate for multi-institution IC technology NDA's modeled after CERN's *Frame Contracts*.
  - Encourage/Support workshops, seminars and Technical Development Short Courses to maintain and renew the design workforce.
  - Use common tools for Design Maintenance / Archiving/Revision among institutions eg. ClioSoft or other...
  - Develop Reliable, Hierarchically compatible, Test Bench techniques for all aspects of ASIC/System designs.





# Topics: some examples

(not intended to be an exhaustive list)

- Electronics and ASICs in extreme environments
  - Cryogenic temperature
  - Extreme radiation environments
- Fast timing
  - Picosecond timing resolution with size and power constraints
  - Precision clock and timing circuits
- Fine granularity, high precision instrumentation
  - Particle flow techniques
  - '4D' particle measurements, combining fine granularity measurements and precision timing



# Topics: some examples

- Low power high speed I/O protocols
  - Power management blocks
- Fault tolerant communication
  - CMOS with integrated photonics
  - Silicon photonics and optical transmission
  - Wireless blocks
  - Low mass cable systems
- Radiation-tolerant Power Systems



# Topics: some examples

- Photonic sensor readout
  - SiPMs cooled and cold.. Precise timing (and/) or photon counting / energy measurement ..
  - Quantum sensors with frequency selected readouts
  - CMOS (or other IC technologies) to replace SQUID readout?
  - RF techniques



# Topics: some examples

- Circuits for monolithic sensors with integrated readout
  - MAPS, SPADs, SiPM
  - Synergies with NP
- New design and verification methodologies
  - Self assembly techniques
- Artificial Intelligence and Machine Learning techniques
  - Internet of Things technology



## Topics: some examples

- Many interfaces with other sub-topical groups
  - Photodetectors, sensors, tracking, calo, TDAQ, etc
  - Will organize joint discussions and meetings

..... We look forward to knowing your list of pressing needs/issues...



# Email lists

Join the Instrumentation Frontier email list: [SNOWMASS-INSTRUMENTATIONFRONTIER@fnal.gov](mailto:SNOWMASS-INSTRUMENTATIONFRONTIER@fnal.gov)

- Topical Group e-mail list: [SNOWMASS-IF-07-ELECTRONICS-ASICS@FNAL.GOV](mailto:SNOWMASS-IF-07-ELECTRONICS-ASICS@FNAL.GOV)

Instruction for joining the mailing list:

- Send an e-mail message to [listserv@fnal.gov](mailto:listserv@fnal.gov)
- Leave the subject line blank
- Type “SUBSCRIBE SNOWMASS FIRSTNAME LASTNAME” (without the quotation marks) in the body of your message. You'll get a Slack invitation when that subscription is approved.



# SLACK channels

Slack channels for topics common to the Instrumentation Frontier: instrumentation

- Slack channel: if07-electronics\_asics

Instruction for joining the SLACK channel

- Go to <https://snowmass2021.slack.com/> If your institution's domain is on the list, join in.
- If your institution is not on the list, send an email to any of the Frontier's conveners to get an invitation.